Historic, Archive Document

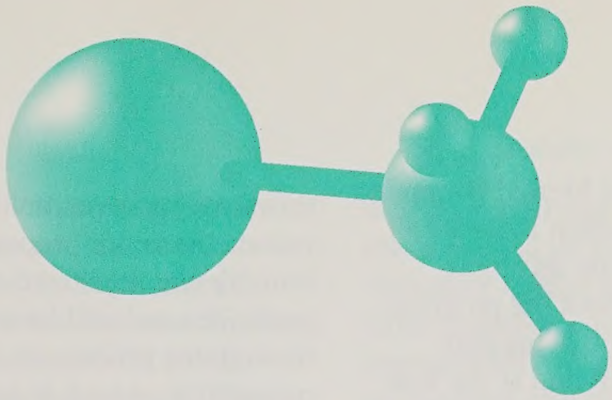
Do not assume content reflects current scientific knowledge, policies, or practices.

aSB952
.B75M47

USDA

Vol. 8, No. 1
July 2002

Methyl Bromide *Alternatives*



Inside This Issue

This issue and all back issues of the *Methyl Bromide Alternatives* newsletter are now available on the Internet at **<http://www.ars.usda.gov/is/np/mba/mebrhp.htm>**.
Visit the ARS methyl bromide research homepage at **<http:/www.ars.usda.gov/ismbmebrweb.htm>**.

This newsletter provides information on research for methyl bromide alternatives from USDA, universities, and industry.

Address technical questions to Kenneth W. Vick, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., Beltsville, MD 20705–5139. Phone (301) 504-532, fax (301) 504–5987.

Address suggestions and requests to be added to the mailing list to Sharon Durham, USDA, ARS, Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705–5129. Phone (301) 504–1611, fax (301) 504–1641.

The Status of Methyl Bromide Alternatives

Methyl bromide's reign as the gold standard of soil fumigants became tarnished as its ozone depleting properties surfaced. In 2005, methyl bromide will be lost to growers as a soil treatment option, and other practices and compounds must fill the void. ARS and others have put significant efforts into researching various ways to fill the gap that will be left when methyl bromide is completely unavailable. This report is a compilation, or a status of sorts, of the leading options available to growers in the United States.

Before the methyl bromide mandatory reductions began in 1999, U.S. agriculture used about 60 million pounds of the fumigant. Soil fumigation accounted for 75 percent of the methyl bromide used, with about 11 percent used to fumigate harvested commodities during storage and import or export. Another 6 percent of methyl bromide was used to fumigate structures such as food processing plants, museums, transport vehicles, and warehouses. The last 8 percent was used to produce other chemicals.

While quarantine use is currently exempted from the upcoming ban, the Montreal Protocol Technology and Economic Assessment Panel may reconsider the exemption. In 1998, the latest year for which statistics are available, the United States used approximately 570,015 pounds for quarantine purposes. In exporting U.S. goods to other countries, fumigation with methyl bromide may be required. Methyl bromide is also used at U.S. ports-of-entry to disinfest commodities found, on inspection, to be infested with nonindigenous pests, the introduction of which may irreparably harm U.S. agriculture.

The primary focus for the U.S. Department of Agriculture in facing the loss of methyl bromide is research, although technology transfer and education activities with the private sector are also included. Additional funding has been given to assist in the registration of potential alternative fumigants. The Agricultural Research Service (ARS), which serves as the lead agency in these activities, has established a national

program called Methyl Bromide Alternatives which includes all ARS research on this topic. Information about the program and the research being conducted can be found at the web site:
http://www.nps.ars.usda.gov.

ARS Research on Alternatives

Preplant Soil Fumigation

Research on preplant soil fumigation consists of investigations of alternatives that use other chemicals, biological controls, disease/pest resistant plants, modified cultural practices, and integrated pest management practices to control weeds, pathogens, nematodes, and damaging insects. Viable methyl bromide alternatives are difficult to identify compared to replacements for other ozone depleters because many factors affect the efficacy: crop and soil type, climate, and target pests. These factors change from one geographical location to another; therefore, it is important to be aware that technology developed in one location is most successfully used in the areas in which the research was conducted. Two chemicals, iodomethane (methyl iodide) and propargyl bromide, have shown promise in field studies. Iodomethane has an advantage over the chemically similar methyl bromide—it photodegrades before reaching the stratosphere, so it is not an ozone-depleting substance. At this time, however, neither iodomethane nor propargyl bromide are registered as pesticides and will have to go through the process of registration, which is costly and time-consuming, before they are available to producers. Also, restrictions on use may be implemented due to concerns about its environmental fate since many of the growing regions are close to schools and residences.

Because the bulk of preplant methyl bromide, nearly 80 percent, is used on strawberries, tomatoes, ornamentals, peppers, and nursery crops, ARS' primary research focus has been on these crops with special emphasis on tomatoes in Florida and strawberries in California as model crops. Additional research has addressed replant difficulties often associated with perennial crops such as grapes, apples, and peaches.

ARS' strategy for evaluating potential alternatives is to first test the approaches in controlled experiments to determine efficacy and follow up with field tests of those determined to be effective. The impact of the variables that affect efficacy is addressed by conducting field trials at multiple locations with different crops and against various diseases and pests. Those alternatives that are effective in field trials are further tested in field-scale validations, often by growers in their own fields. Research teams that include ARS and university scientists, extension personnel, and grower representatives meet periodically to evaluate research results and plan future trials.

Vegetable Crops

In the United States, tomato crop production uses 24 percent of preplant methyl bromide, more than any other crop. Peppers account for 12 percent. Methyl bromide is used for preplant fumigation of soil in both nurseries and fields before transplanting. Target pests include soil-borne pathogens, particularly *Fusarium oxysporum, Phythium* spp., and *Phytophthora* spp.; nematodes, especially root knot nematodes (*Meloidogyne* spp.); and weeds such as purslanes, spurges, and nutsedges.

The most promising fumigant alternatives for control of nematodes, pathogens, and weeds are a combination of metam-sodium plus chloropicrin, Telone (1,3-dichloropropene, or 1,3-D) C-17 (83 percent 1,3-D and 17 percent chloropicrin), Telone C-35 (65 percent 1,3-D and 35 percent chloropicrin), propargyl bromide, pebulate (Tillam) plus Telone C-17, and iodomethane (methyl iodide), according to research results in 2000 from Dr. Joseph Noling, an extension nematologist with the University of Florida's Institute of Food and Agricultural Sciences at Lake Alfred, Florida.

According to a 1997 U.S. EPA study, metam-sodium and plastic mulch controlled all weeds tested in the southeastern United States except nutsedge, the most bothersome weed in horticultural crops. Noling reports that metam-sodium displays erratic control, with excellent control in some studies and very little in others. Although this variability is attributed to differences in application, it still presents a major shortcoming. The use of paper mulch, a cultural approach, is also being studied for nutsedge control. Preliminary small-scale tests have demonstrated good nutsedge suppression, and this approach also eliminates the need for polyethylene mulch. Although this research has just been started, it reflects that long-term, more sustainable approaches are being studied in addition to short-term, chemical alternatives.

While biological controls show promise for control of pathogens and weeds in vegetable nurseries and production fields, effective control may require several years of continuous treatment. Another possible biological control is competitive displacement of pathogenic organisms in soil through the use of nonpathogenic organisms and soil amendments. In another approach, Nancy Kokalis-Burrelle at USDA's U.S. Horticultural Research Laboratory at Fort Pierce, Florida, uses plant growth promoting rhizobacteria (PGPR) that have enhanced the growth of tomato and pepper transplants and increased tomato yields. Incidence of *Fusarium* was decreased in this study in some PGPR plots. Studies conducted by C. Douglas Boyette at USDA's Southern Weed Science Research Unit at Stoneville, Mississippi, indicate that a fungal pathogen, *Myurothecium verrucaria*, shows promise for controlling weeds in pepper and tomato plots without affecting the transplants. Additional biological control agents that are under development include *Dactylaria higginsii*, which, after having been shown to be extremely effective in controlling purple nutsedge in small-scale field trials, is now under evaluation by Erin Rosskopf in large-scale plots through a cooperative research project between USDA and the University of Florida. Rosskopf, a research microbiologist at USDA's U.S. Horticultural Research Laboratory in Fort Pierce, Florida, is also developing a biological control agent, *Phomopsis amaranthicola,* for use in vegetables and ornamentals. This fungal plant pathogen significantly affects the growth of pigweeds (*Amaranthus* spp.) and has been field-tested in small-scale trials over several seasons.

Cultural controls, another nonchemical approach, show promise and are under continual testing. A period of several years is necessary for this approach to work at an optimal level since pest population levels are reduced each successive year. Bell and chili peppers that demonstrate high levels of resistance to root-knot nematodes have been developed and commercially released. Crop rotation has reduced nematode populations in pepper fields, resulting in increased yield. Soil solarization, though it works well on occasion, has performed inconsistently. Water quality issues have limited the practice of flooding fields to kill pests in regions that have a high water table, such as some parts of Florida.

Strawberries

Producers of strawberries are the second largest preplant users of methyl bromide in the United States, targeting pests such as soil-borne pathogens, nematodes, and weeds. Soil-borne pathogens of particular note are *Phytophthora, Phythium, Rhizoctonia,* and *Verticillium dahliae.* Methyl bromide is used for preplant treatment of soil in nurseries and in production fields before transplanting strawberries. In the nursery industry, the use of methyl bromide is critical because healthy, vigorous plants provide growers with a fighting chance to control disease problems in the field.

In the field of nonchemical approaches, several PGPR strains seem to enhance the growth of strawberries and are being further tested in field studies. While resistance to fungal pathogens is under

evaluation, only low levels of resistance have been identified. Soil solarization, in limited field trials in Florida, has shown yields that are comparable to those of methyl bromide treated plots, although unpredictable weather events will limit its usefulness. In California, where most commercial strawberries are grown, soil solarization is not an option due to a lack of solar radiation and low temperatures.

Thomas Trout of ARS' Water Management Research Laboratory in Parlier, California, and Hussein Ajwa (formerly of the Water Management Research Laboratory, now with University of California-Davis) found that various mixtures of 1,3-D/chloropicrin resulted in yields comparable to methyl bromide fumigation. Continuing studies are being conducted to determine minimum effective rates, optimum application conditions, and the impact of virtually impermeable film on efficacy and rate of application. Ajwa and Trout, in conjunction with the California Strawberry Commission, conducted 4 years of field trials in growers' fields to test and demonstrate the most likely effective alternatives to methyl bromide fumigation for preplant soil treatment for strawberries. Nearly all California strawberries are grown with preplant fumigation with methyl bromide/chloropicrin mixtures, which typically doubles marketable yield. Mixtures of 1,3-D and chloropicrin and chloropicrin alone, in Ajwa and Trout's research plots in 2000, seem to give good response with slightly smaller yields (5 to 15 percent) compared to those with methyl bromide. These chemical alternatives have disadvantages that include greater weed problems, especially with chloropicrin alone; longer waiting times before planting; and regulatory limitations on use. Drip application, according to current studies, may reduce emissions and worker risk. Although fungicides, such as metalazyl (Ridomil) and fosetyl-aluminum (Aliette), slowly reduce a portion of the fungal spectrum encountered in fields over a period of years, the lack of control of other pathogens does not support this approach. It appears that in the near future, alternative chemical fumigants are the only technology likely to replace methyl bromide for control of soilborne pathogens in strawberry nurseries and production fields.

Grapes, Fruit Trees, and Nut Trees

Methyl bromide has been used for fumigating soil before planting or replanting to kill pathogens and plant parasitic nematodes in the soil. Methyl bromide is capable of destroying most life stages of soil-dwelling organisms as well as the roots of old trees and vines. Without fumigation, roots are likely to remain present for at least 3 years after tree removal. These woody roots provide a food source for a variety of soilborne nematodes, insects, and plant pathogens. Viruses, bacteria, and other microorganisms, like fungi, will remain in the soil for as long as the food source is available.

Developing alternatives to methyl bromide for replant of vineyards, as well as fruit and nut trees, is particularly challenging because the results of these studies can only be ascertained over a period of years. Scientists have not been able to isolate pathogens that consistently cause replant disorder. Various species of nematodes are present in the soils, such as ring nematodes in sandy soils and pin nematodes in sandy-loam soils. In some instances of replant disorder, small roots are evident but no obvious pathogens are present.

A number of nonchemical approaches are being explored, including biocontrol and growth enhancement agents. Results of these studies are several years away. A number of cultural control methods appear promising. Some field studies have been set up to determine whether fallowing for several months to several years and the use of cover crops may alleviate replant disorder. The use of some wheat cultivars as a cover crop seems to reduce levels of pathogenic microbes in apple orchards, according to Mark Mazzola, a plant pathologist in ARS' Tree Fruit Research Laboratory in Wenatchee, Washington, and Yu Huan Gu, formerly of the Tree Fruit Research Laboratory, in studies

conducted in 2000. Under certain conditions, preplant soil solarization also appears to be a viable alternative for control of the ring nematode (*Criconella xenoplax*) in orchards. Alterations in cultural practices, such as soil excavation in the fall prior to planting and subsequent exposure of this soil to freeze/thaw cycling during the winter, or establishing new plants in the old aisle rather than the old row, appear effective in reducing replant problems.

Another viable alternative to methyl bromide for some trees seems to be host-plant resistance; for example, "Deep Purple" rootstock for fruit and nut trees appears resistant to pathogens in orchards. However, graft compatibility determinations require waiting for symptoms to appear, which can take years. "Guardian" rootstock demonstrates exceptional resistance to peach tree short life induced, in part, by the ring nematode and may prove to be a viable alternative to preplant methyl bromide fumigation for nematode control.

At ARS' Water Management Research Laboratory in Parlier, California, Cynthia Eayre is investigating chemical controls. Preliminary results from 2 years of data, reported in 2000, show that iodomethane effectively controls peach replant disorder. Combinations of resistant rootstock and either 1,3-D or metam-sodium also appear to be possible alternatives for methyl bromide for control of peach replant disorder. Fungicides to control soil-borne pathogens have been used unsuccessfully.

Sally Schneider, also of ARS' Water Management Research Laboratory, treated a 65-year-old vineyard that was infested with significant plant parasitic nematode populations with drip-applied Telone II EC and shank-applied iodomethane. The field was then replanted with three grape rootstocks that demonstrated broad resistance to most nematodes in grape production areas. Three years after planting, the Harmony rootstock supports minimal populations of the root knot nematode, even in untreated plots, but supports higher populations of the citrus nematodes than either Thompson Seedless or Teleki 5C. Iodomethane and Telone/Vapam combinations appeared to act as adequate replacements during the 3-year evaluation.

Postharvest Research

Developing alternatives for controlling pests of stored and exported commodities is the realm of postharvest research. Many commodities cannot be exported legally without methyl bromide treatment to eradicate quarantine pests and certify the commodities pest free. Alternative fumigants, heat and cold treatments, modified atmospheres, and combinations of treatments are various research approaches being explored.

Dried Fruits and Nuts

Low-temperature (10 °C) storage and controlled-atmosphere (5 percent O_2) storage were found to effectively control pests of dried fruits and nuts.

Fresh Fruits

In a number of crops, including citrus and papaya exported from Hawaii and other places and limes imported into Florida, the use of forced hot air for quarantine treatment of fresh fruits has been commercialized. Hot water immersion for quarantine treatment has been commercialized for litchi exported from Hawaii and guavas exported from Florida. Conversely, cold treatments are used commercially for avocado and starfruit exported from Hawaii. Large-scale tests have shown irradiation to be effective for disinfestation of sweetpotato weevils in sweetpotatoes exported from Florida, Malaysian and other fruit flies in fruits exported from Hawaii, and maggots in blueberries exported from Florida. Field-study results are used to establish and maintain pest-free zones in lieu of postharvest treatments for fruit flies in citrus exported from Texas. Approximately two-thirds of the fruit, in most years, can be harvested under the requirements of a pest-free zone so that methyl bromide treatment is not required.

Processing Facilities and Warehouses

Methyl bromide is used by many food companies to fumigate processing facilities and storage areas to rid these areas of insect pests. A proven alternative treatment is raising the temperature of the facilities to near 50 °C for 2 to 3 days. Also, a combination of heat and diatomaceous earth seems particularly effective in areas that may be difficult to heat.

Emissions Reductions

A methyl bromide recapture and recycling system was designed by ARS and commercialized, and is now in operation at the Dallas-Fort Worth International Airport. The pilot recapture system vastly reduced the amount of methyl bromide released to the atmosphere—93 to 96 percent of recoverable methyl bromide is captured by the carbon in field tests.

Conclusions

Currently registered alternative fumigants such as metam-sodium, chloropicrin, and 1,3-D seem likely to be the most reliable replacements. However, it is probable that the replacements will not be as reliable as methyl bromide in all cases. These alternatives were once the standard chemicals used but in many cases were replaced by methyl bromide.

For preplant purposes, biological control and host-plant resistance may demonstrate effectiveness in some cases in the future. Much of the research on these approaches is still to be conducted, and it is unlikely that economic use of these alternatives will be available for many uses before the 2005 phase-out has occurred. Due to the multiple combinations of crop, pest or pathogen, environmental conditions, weed species, soil type, etc., combinations of approaches will be necessary to effectively manage diseases and pests.

For postharvest and export uses, several nonchemical approaches, such as heat/cold treatments and modified atmospheres, demonstrate some possibilities as methyl bromide alternatives. A methyl bromide recapture system has been developed and is in use at one airport in Texas.

Research is only one cog in the machinery to bring reliable, effective, and economical methyl bromide alternatives to farmers and other users of methyl bromide. A critical role must be filled by the chemical industry: registering and marketing any promising unregistered alternatives. It is currently uncertain if there is adequate financial incentive for the chemical industry to bring new products to market in light of the minor-use nature of methyl bromide. Users of methyl bromide will ultimately make decisions, based on several factors including economic considerations, as to whether to utilize any alternative technologies that become available.

Plantpro 45 as a Control of Soil-Borne Pathogens, Weeds, Nematodes, and Seed-Borne Pathogens

Plantpro 45, a low-risk iodine-based compound, was studied by Nancy Kokalis-Burelle to ascertain its usefulness for soil-borne pathogen and weed control. The results are somewhat mixed. Two years of greenhouse and field trials have shown that Plantpro 45 has some potential for control of root-knot and sting nematodes, some soil-borne fungal and bacterial pathogens, seed-borne fungal pathogens, and economically important weed species.

"Plantpro 45 works by disrupting membranes in organisms. When compounds are in contact with nematodes and eggs in the lab you get good toxicity, but in the soil the effect is lessened," says Burelle. "Soil is a very complex medium and water doesn't move through the soil as expected, and results vary from trial to trial."

Nematode Control

Plantpro 45 showed some reduction of root-knot nematode damage on tomato at multiple field locations in Florida. However, Burelle found it didn't perform as well as methyl bromide.

In field trials conducted in cooperation with the IR-4 methyl bromide alternatives research program on strawberries in Florida, Plantpro 45 seemed to control soil populations of sting nematode. In two locations, nematodes were reduced from about 175 nematodes per 250 cc of soil in the untreated plots to approximately 50 in the Plantpro 45 (plus Devrinol) plot and about 25 nematodes per 250 cc of soil in the methyl bromide treated plot. In another IR-4 trial at Duke Farm, Dover, Florida, a combination of Plantpro 45 + Fosthiazate + Devrinol brought sting nematode levels to 0.8 per 100 cc of soil compared to 29.3 per 100 cc of soil in the untreated control plot. When a combination of only Plantpro 45 + Devrinol was used, the sting nematode population was reduced to 6.8 per 100 cc soil.

Efficacy for nematode control was not tested in the IR-4 California strawberry trials, since plant parasitic nematodes are not widely prevalent in California soils cropped to strawberries due to a lack of sandy soil, the nematode's preferred environment, explained Mike Nelson of Plant Sciences, Inc. (Watsonville, California). In addition, Nelson found that Plantpro 45 seems to confer some fungicidal benefits; for instance, it controls *Rhizoctonia* at upper soil depths and meets industry standards.

Fungal and Bacterial Control

In several locations in Florida, Plantpro 45 demonstrated fungicidal and bactericidal effects by providing significant control of Fusarium crown rot and bacterial wilt of tomato in naturally infested fields. Under greenhouse conditions, a soil drenching with Plantpro 45 of 80 ppm followed by a planting 21 days later and a foliar application at 80 ppm 1 week after planting increased root and shoot weight and improved root condition of tomato when grown in field soil naturally infested with Fusarium crown rot.

In an IR-4 tomato trial carried out in southern California (Tustin, Orange County), by Nelson, a preplant application of Plantpro 45 (1X rate of 142 gallons per treated acre, applied in 1.5 inches of water), gave control of *Rhizoctonia solani* comparable to that of the methyl bromide/chloropicrin standard at the 6-inch soil depth. However, a postplant application at a reduced rate of (63 gallons per treated acre, also applied in 1.5 inches of water), did not provide similar control of this soil-borne pathogen.

Crop Performance

In IR-4 tomato trials conducted over a 2-year period in California, Plantpro 45 treatments produced marketable fruit yields comparable to the industry standard, according to Nelson. "Plantpro 45 produced the best looking fruit and best yield in tomatoes." At the Oceanside, California, site during 2001 trials, Plantpro 45 (3/4X) + metam (applied as a bed-top broadcast spray strictly for weed control) outperformed all alternatives in yield, producing 5,069 25-pound cartons/acre compared to 5,059 25-pound cartons/acre produced by a combination of methyl bromide and chloropicrin (50/50) and 4,518 25-pound cartons/acre in the untreated control.

Strawberry trials in Oxnard and Salinas, California, produced mixed results. During first-year trials (2000 fall planting/2001 harvesting), plants were substantially less vigorous in Plantpro 45 treated plots, relative to the methyl bromide/chloropicrin treated plots. However, Nelson notes that the compound was applied both as preplant treatment and as postplant treatment applications and that the postplant applications in particular appeared to inhibit growth of the strawberry plants. In the second-year trials (2001 fall planting/2002 harvesting), the postplant application was eliminated and vigor improved. Plants will continue fruiting until June 2002 in the southern California (Oxnard) trial and until late October 2002 in the northern California (Salinas) trial, at which times the season-total fruit yields will be assessed.

Burelle notes that Plantpro 45 can negatively impact crop growth. "Postplant applications

should not be attempted on peppers or strawberries since they are especially sensitive to the chemical and should be closely monitored on all other crops."

Weed Control

Plantpro 45 does provide some weed control, according to Burelle's study. Multiple greenhouse experiments on weed infestation levels in naturally weed-infested soil showed that Plantpro 45 has potential to control one of Florida's major herbaceous weed species in vegetable crops: purslane *(Portulaca oleracea).* Further studies on the herbicidal effects of Plantpro 45 confirm significant reductions in populations of nightshade, purple and yellow nutsedge, and crabgrass. High-foliar applications of Plantpro 45 on emerged weeds, followed by rototilling prior to planting, provided effective control of weed species without phytotoxic effects on tomato when an interval of 21 days was allowed before planting and adequate soil moisture was maintained between application and planting.

In contrast, in Nelson's 2001 California tomato trials mortality of annual bluegrass and common purslane buried 6 inches deep prior to application of Plantpro 45 was significantly lower, relative to the methyl bromide/chloropicrin standard, and not statistically different from that of the untreated control. Further, mixed results were observed in the 2000 Florida tomato trials. At the Lake Jem trial site, the combinations of Plantpro 45 + metam (applied as a bed-top broadcast spray strictly for weed control) did not significantly control yellow nutsedge. However, at the Live Oak trial site, the Plantpro 45 (1X) + metam (metam again used strictly for weed control) combinations reduced the incidence of this weed species to a level comparable to that of the methyl bromide/chloropicrin standard.

Seed Treatment

In a different application, Plantpro 45 seems to also provide some efficacy as a seed treatment. Burelle worked with an oriental-vegetable grower who had a problem with *Fusarium.* "Plantpro 45 has good potential as a seed treatment," says Burelle. Further studies are needed.

Technical Report

Methyl Bromide Alternatives and Their Current Limitations in Florida

James P. Gilreath, University of Florida, Gulf Coast Research and Education Center, Bradenton, Florida

While there are many limitations to the adoption of methyl bromide alternatives in Florida, those limitations are much different from the principal ones in California in that they are not State regulatory driven, at least not at this time. Telone products, including Telone II (1,3-dichloropropene) and Telone C-17 and Telone C-35 (mixtures of 1,3-dichloropropene and chloropicrin), constitute the most likely replacements for methyl bromide in many crops in Florida, including vegetables and ornamentals.

Large-scale trials have demonstrated these products on grower farms, especially tomato farms. One of the main obstacles for adoption of alternatives is nutsedge control, and most of the currently available alternatives either provide no control or erratic performance in Florida soils. Tillam has been identified as a herbicide which can be used in conjunction with Telone to provide nutsedge control; however, it is only labeled in tomato and has produced crop damage in some cases. In general, it is felt that these instances of phytotoxicity were the result of improper application or inadequate soil incorporation, as performance has been acceptable in most of the large-scale trials conducted on grower farms. Tomato growers are fortunate in this regard for they have an effective herbicide; however, there are many crops where herbicide options are few, including pepper, eggplant, and cucurbits like watermelon.

Ornamental growers, such as producers of caladiums and cut flowers, have seen little research on their crops and thus are much farther behind tomato

and pepper in the selection and development of alternative strategies.

Telone products have two problems, and these are shared by some of the other alternatives: excessive personal protective equipment (PPE) requirements and setback or buffer space requirements. Buffers of 300 ft. from occupied structures are not a problem for most tomato growers, but for the bulk of the Florida strawberry industry, they are a major deterrent. Most of the production is situated in the Plant City area of Florida. Plant City has become a bedroom community of one of our largest cities, Tampa, and berry fields are generally located within what has become residential areas. Some fields have housing developments on three sides and a road on the fourth. The average strawberry field is 20 acres or less. The arable area of a 20-acre field gets very small when a 300-ft. buffer is imposed, and even smaller if it is interpreted as commencing not from the actual dwelling but from the property line. Thus, Florida strawberry growers do not feel that Telone products are a viable alternative for them. Telone may be efficacious and result in good fruit production, but the buffer may render it impractical for berry growers.

While all seems positive for tomato growers, they do share a common problem with other producers who may rely on Telone products, and that is the PPE issue. The use of a full-face respirator, rubber gloves, and boots and coveralls all but kills any chance of Telone being used in Florida, especially during the fall season. Our tropical to subtropical climate makes it extremely difficult to work in the required PPE, and heat stress becomes a major issue. Realistically, heat stress may not be a problem because workers are not likely to work under those conditions; thus the real problem would be an inability to fumigate soil for crop production and the resultant economic hardship the grower would experience.

In an effort to deal with or circumvent the PPE issue, those of us working in Florida have investigated broadcast application as an alternative to in-bed application of Telone products. Broadcast application would involve one person in an air-conditioned tractor cab with appropriate PPE and carbon filtration of recirculating air, thus greatly reducing the impact of PPE to a manageable level. While this sounds like a good idea, little data exist for the efficacy of Telone and chloropicrin mixtures when applied to nonbedded soil without polyethylene mulch covering it.

This launched a new wave of research activity wherein broadcast was compared to in-bed applications of Telone C-17 and C-35. Telone II (1,3-D) has been applied broadcast or in-bed without mulch in potatoes for years, and nematode control efficacy has been well documented. The real question was not so much whether Telone (1,3-D) would work, but rather whether chloropicrin would work under nonmulched conditions. There was some concern that the higher vapor pressure of chloropicrin would allow it to escape too quickly to kill pathogenic fungi near the soil surface.

Several large-scale trials were conducted on grower farms, and disease control appeared to be comparable between the two application methods, but anecdotal information suggested that some diseases may not be controlled as well as Fusarium wilt race 3 appeared to be controlled in these trials. Results of small-plot experiments with tomato last fall and again this spring demonstrated that disease control could be compromised. As a result, most grower trial applications now consist of Telone II or Telone C-35 broadcast with additional chloropicrin applied to the soil in the bed at the time of bed formation. Some cases exist where the application of chloropicrin both broadcast and in-bed is beneficial.

Broadcast application appears to be the answer to the PPE issue, but it in itself introduces other potential problems. In order to make the application, allow sufficient time for the product to work and dissipate, then re-enter the treated field, form beds, and wait for the dissipation of chloropicrin, a

grower must allow at least 3 weeks for what once required 10 days to 2 weeks with methyl bromide. Summer, when fumigant is being applied for fall production, is the time wherein most of the rainfall for the year occurs in peninsular Florida. This can greatly disrupt soil fumigation activities and result in even greater delays in planting in August and September, thus making it more difficult for growers to develop and adhere to any type of production schedule.

During December, January, and early February, when soil fumigants are applied for the spring crop, soil moisture often is low and this extra time for fumigation increases irrigation water needs by increasing the time over which it is necessary to maintain field moisture at the point required for good biological activity. Since growers are budgeted by the water management districts for water consumption, this reduces the quantity of water available for use by the crop.

The spring production season is Florida's dry season and rainfall is sparse; thus growers rely heavily on well water for irrigation during what is the largest production season. If the pre-wet period is too short, soilborne pests may be inactive and more difficult to kill, and fumigant failure can occur. This was the situation on several farms in Florida this spring, and rootknot nematodes were a problem even in fields fumigated with methyl bromide. If a grower uses too much water for initial land preparation and fumigation, he may exhaust his permitted quantity before the crop is ready for harvest.

One of the big advances to come out of the broadcast application effort has been the tremendous improvement in application equipment. Previous equipment left much to be desired and resulted in erratic performance in some trials. Many different pieces of equipment were tried before the ultimate winner would be identified.

Today, all broadcast applications in research trials in Florida are being made with what is known as the Yetter rig. This equipment, manufactured by Yetter Equipment Co., consists of a series of 30-inch coulters with a forward-swept knife or chisel behind each one with a small "beaver tail" on it, and behind that rolls a set of press wheels which seal the soil surface. The coulters are positioned 1 foot apart. This equipment was pioneered in Florida by John Mirusso, who first saw it at a farm show in the northeast where it was being used for delivery of liquid manures.

Use of this equipment has resulted in much more uniform results and improved efficacy. One of the big advantages of the Yetter rig is that it places the Telone about 12 inches deep where nematodes may escape the effect of the more typical 6 to 8 inch deep applications. In addition, it does not drag plastic mulch and string around a field creating large chisel tracks and the resultant loss of fumigant. Instead, the coulter cuts through this and other debris and provides a more narrow kerf which is easier to seal.

While we have worked a lot on minimization of the impact of PPE by developing broadcast application of Telone, we also have investigated application of fumigants through the drip irrigation system as a means of improving delivery and handling and reduction of worker exposure and the negative implications of PPE requirements.

Applications through drip irrigation tubing would not only reduce the impact of PPE by reducing the number of people involved and allow development of a closed delivery system, but it also would allow fumigant delivery for "double cropping" where the old polyethylene mulch and drip tubing are being used for a second crop in the same beds.

Drip application of any fumigant is a challenge in Florida's sandy soils. Most of our production soils are classified as fine sands with less than 1 percent organic matter, no clay, and very little silt. These soils tend to be droughty and do not favor lateral movement of water or other liquids.

Several years ago drip delivery of Telone was attempted in research trials in Florida and it was not successful. Since that time we have studied the delivery and distribution of water via drip irrigation tubing and have a much better understanding of the downward and lateral movement of water in beds and have investigated multiple tubes, adjuvants, water volumes, pressures, and run times to understand what might improve the delivery of a water-soluble pesticide in our soils.

We now feel we can achieve better results than in the past, but one obstacle still remains: weed control in the bed.

While Telone may provide the nematode control we need, it will not control weeds like nutsedge. We still need a herbicide or some other product which can give us this control. Metam may be an option for our weed control needs, but its performance has been erratic in past research in Florida, and the one thing growers require of any alternative is consistency.

Much research has been conducted on the application of metam in Florida, recognizing that proper application was the key to improved efficacy. Decreased chisel spacing, high-pressure injection, disk incorporation, rototiller incorporation, delivery through the drip irrigation system, and many other techniques have been investigated, but the one which has been the most efficacious has been rototiller incorporation followed by either immediate bed formation or power rolling the soil surface to seal it.

Drip irrigation delivery has resulted in narrow bands of nutsedge control in the past, but just as was true with Telone a lot depends upon the actual mechanics of the application and we still have a lot to learn. Drip delivery would be more acceptable to most growers if we could improve efficacy, because rototillers are slow, require a lot of horsepower, and few growers own one.

A few growers who have experimented with metam application on a broadcast basis followed by bed formation soon afterward have complained about the fumes and had problems getting their labor to stay on the job. At least one Florida grower is using it in this fashion. Overall, we still have work to do to improve application technology for metam.

A final problem identified with metam is the volume of product required per acre and the need for delivery and storage facilities for a large farm. One hundred acres of tomatoes would require 7,500 gallons of metam, and that is a lot of product to handle. Application through the drip irrigation system would make that a more manageable task, but storage and delivery problems would still exist to some extent. Hopefully, there will not be any surprises in the form of PPE or buffer zones for metam or chloropicrin when they go through re-registration.

Chloropicrin's future is tied to partnering with Telone for the most part, as alone it is not considered an effective nematicide and provides poor to no weed control. While it is an excellent fungicide for soil-borne pathogens, soil-borne pest control needs are seldom only diseases and are usually a complex of disease with nematodes or weeds or all three combined.

While there are other products being considered as potential alternatives, Telone and chloropicrin are the most likely immediate successors to methyl bromide. Lack of enough data, efficacy problems, and the lack of handling experience with many of these other products make them less likely to become common "household words" in the near future.

The last impediment I would like to discuss is what I call a grower's "comfort level." I asked two of my best tomato grower cooperators if they were comfortable with Telone C-35 plus Tillam herbicide. Each told me the same thing: "I have seen it in your experiments each season here on my farm for at least the last 5 years and the results have been good. I don't think we have had any problems with it or lost much production, if any, but when you ask me if I am comfortable with it, I have to say I am not. I know what

methyl bromide will do because I have used it for many years and there is a lot to be said for the short time interval between application and planting and the wide range of conditions under which I can apply it and still get acceptable control. Use of Tillam makes me nervous because I am not used to applying a herbicide, and my experience with herbicides has been to kill things and I have even damaged tomatoes with it. Am I comfortable with this as an alternative? No. That does not mean that I cannot become comfortable with an alternative, but right now I am not comfortable with this and will have to ease into it slowly."

Comfort is that feeling we have from knowing something well. This level of knowledge is only attained through prolonged exposure and positive experiences. Comfort will not come overnight, and any negative experience can set back the progress made to date tremendously. This is why as scientists we must try to anticipate the problems and address them before they reach the grower. Additionally, we need to work closely with growers to introduce them to the alternatives we recommend and any other new technology associated with their use to assure an easy transition so there are viable alternatives with which our growers feel comfortable. Only then is our job complete.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

The United States Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720–2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326–W, Whitten Building, 1400 Independence Avenue, SW, Washington, D.C. 20250–9410 or call 202–720–5964 (voice and TDD). USDA is an equal opportunity provider and employer.